ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICES WITH ENHANCED ARCING DETECTION AND SUPPRESSION FEATURES

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Priority Claim

[0001] This application claims priority under 35 U.S.C. 119(e) to U.S. Provisional Patent Application No. 60/477,980, filed June 12, 2003, entitled "ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICES WITH ENHANCED ARCING DETECTION AND SUPPRESSION FEATURES," which is incorporated herein by reference.

Related Application:

[0002] This application is related to commonly assigned U.S. Patent Application No. 10/435,289, filed May 9, 2003, entitled "ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICES WITH SPECIAL DETECTORS AND INDICATORS" (Attorney Docket No. SHPR-01028USD), which is incorporated herein by reference.

Field of the Invention:

[0003] The present invention relates generally to devices that transport and/or condition air.

Background of the Invention:

[0004] Fig. 1 depicts a generic electro-kinetic device **10** to condition air. Device **10** includes a housing **20** that typically has at least one air input **30** and at least one air output **40**. Within housing **20** there is disposed an electrode assembly or system **50** comprising a first electrode array **60** having at least one electrode **70** and comprising a second electrode array **80** having at least one electrode **90**. System **10** further includes a high voltage generator **95** coupled between the first and second electrode arrays. As a result, ozone and ionized particles of air are generated within device **10**, and there is an electro-kinetic flow of air in the direction from the first electrode array **60** towards the second electrode array **80**. In Fig. 1, the large arrow denoted IN represents ambient air that can enter input port **30**. The small "x"'s denote particulate matter that may be present in the incoming ambient air. The air movement is in the direction of the large arrows, and the output airflow, denoted OUT, exits device **10** via outlet **40**. An advantage of electro-kinetic devices such as device **10** is that an airflow is created without using fans or other moving parts. Thus, device **10** in Fig. 1 can function somewhat as a fan to create an output airflow, but without requiring moving parts.

[0005] Preferably particulate matter "x" in the ambient air can be electrostatically attracted to the second electrode array **80**, with the result that the outflow (OUT) of air from device **10** not only contains ozone and ionized air, but can be cleaner than the ambient air. In such devices, it can become necessary to occasionally clean the second electrode array electrodes **80** to remove particulate matter and other debris from the surface of electrodes **90**. Accordingly, the outflow of air (OUT) is conditioned in that particulate matter is removed and the outflow includes appropriate amounts of ozone, and some ions.

[0006] An outflow of air containing ions and ozone may not, however, destroy or significantly reduce microorganisms such as germs, bacteria, fungi, viruses, and the like, collectively hereinafter "microorganisms." It is known in the art to destroy such microorganisms with, by way of example only, germicidal lamps. Such lamps can emit ultraviolet radiation having a wavelength of about 254 nm. For example, devices to condition air using mechanical fans, HEPA filters, and germicidal lamps are sold commercially by companies such as Austin Air, C.A.R.E. 2000, Amaircare, and others. Often these devices are somewhat cumbersome, and have the size and bulk of a small filing cabinet. Although such fan-powered devices can reduce or destroy microorganisms, the devices tend to be bulky, and are not necessarily silent in operation.

Summary of the Present Invention:

[0007] Embodiments of the present invention relate to systems and methods for monitoring and suppressing arcing between a first electrode and a second electrode of an electro-kinetic system. A current (or voltage) associated with the arcing condition of the electro-kinetic system is monitored in order to adjust a first count and a second count. Each time a monitored value reaches a threshold, the first count is incremented. Each time the first count reaches a first count threshold (e.g., 30), the electro-kinetic system is temporarily shut down (or power is lowered) for a predetermined period (e.g., 80 seconds), the second count is incremented, and the first count is reset. The electro-kinetic system restarts (or the previous power level is returned) after the predetermined period. When the second count reaches a second count threshold (e.g., 3), the electro-kinetic system is shut-down until a reset condition is satisfied.

[0008] In accordance with an embodiment of the present invention, monitoring includes periodically sampling the current (or voltage) associated with the electro-kinetic system. These samples are compared to the threshold, which is a current threshold if a current is being sampled. This can alternatively be a voltage threshold if a voltage is being sampled. In accordance with an embodiment of the present inventions, a running average of the samples is produced and the running average is compared to the current or voltage threshold.

[0009] In accordance with an embodiment of the present invention, after the second count reaches the second count threshold, the electro-kinetic system remains shut-down until the second electrode is removed and replaced, or, until a power control switch is turned off and back on. In response to detecting removal and replacement of the second electrode, or turning off and on the power control switch, the first and second counts are reset and the electro-kinetic system is restarted. In accordance with an embodiment of the present invention, the first and second counts are reset when the sampled current (or voltage) does not exceed the threshold for an extended period (e.g., 60 seconds).

[0010] Embodiments of the present invention also provide systems and methods for compensating for variations in line voltages used to power an electro-kinetic air transporter and conditioner device. The electro-kinetic air transporter and conditioner device includes a high voltage generator that provides a potential difference between at least one emitter electrode and at least one collector electrode. The high voltage generator is driven by both a DC voltage obtained from an AC voltage source, and a low voltage pulse signal. The DC voltage is stepped down to produce a voltage sense signal indicative of a level of the AC voltage source. The voltage sense signal is monitored. At least one of a pulse width, duty cycle and frequency of the low voltage pulse signal is adjusted,

based on the monitored voltage sense signal, in order to substantially maintain the potential difference at a desired level.

[0011] Other features and advantages of the invention will appear from the following description in which the preferred embodiments have been set forth in detail, in conjunction with the accompanying drawings and claims.

Brief Description of the Figures:

[0012] FIG. 1 depicts a generic electro-kinetic conditioner device that outputs ionized air and ozone, according to the prior art;

[0013] FIGS. 2A-2B; Fig. 2A is a perspective view of an embodiment of the housing for the present invention; Fig. 2B is a perspective view of the embodiment shown in Fig. 2A, illustrating the removable array of second electrodes;

[0014] FIGS. 3A-3E; Fig. 3A is a perspective view of an embodiment of the present invention without a base; Fig. 3B is a top view of the embodiment of the present invention illustrated in Fig. 3A; Fig. 3C is a partial perspective view of the embodiment shown in Figs. 3A-3B, illustrating the removable second array of electrodes; Fig. 3D is a side view of the embodiment of the present invention of Fig. 3A including a base; Fig. 3E is a perspective view of the embodiment in Fig. 3D, illustrating a removable rear panel which exposes a germicidal lamp;

[0015] FIG. 4 is a perspective view of another embodiment of the present invention;

[0016] FIGS. 5A-5B; Fig. 5A is a top, partial cross-sectioned view of an embodiment of the present invention, illustrating one configuration of the germicidal lamp; Fig. 5B is a top, partial

cross-sectioned view of another embodiment of the present invention, illustrating another configuration of the germicidal lamp;

[0017] FIG. 6 is a top, partial cross-sectional view of yet another embodiment of the present invention;

[0018] FIG. 7 is an electrical block diagram of an embodiment of a circuit of the present invention; and

[0019] FIG. 8 is a flow diagram used to describe embodiments of the present invention that sense and suppress arcing.

Detailed Description of the Preferred Embodiment:

Overall Air Transporter-Conditioner System Configuration:

Figs. 2A-2B

[0020] Figs. 2A-2B depicts a system which does not have incorporated therein a germicidal lamp. However, these embodiments do include other aspects such as the removable second electrodes which can be included in the other described embodiments.

[0021] Figs. 2A and 2B depict an electro-kinetic air transporter-conditioner system **100** whose housing **102** includes preferably rear-located intake vents or louvers **104** and preferably front located exhaust vents **106**, and a base pedestal **108**. Preferably, the housing **102** is free standing and/or upstandingly vertical and/or elongated. Internal to the transporter housing **102** is an ion generating unit **160**, preferably powered by an AC:DC power supply that is energizable or excitable using switch **S1**. Switch **S1**, along with the other below described user operated switches, are

conveniently located at the top **103** of the unit **100**. Ion generating unit **160** is self-contained in that other ambient air, nothing is required from beyond the transporter housing **102**, save external operating potential, for operation of the present invention.

[0022] The upper surface **103** of the housing **102** includes a user-liftable handle member **112** to which is affixed a second array **240** of collector electrodes **242**. The housing **102** also encloses a first array of emitter electrodes **230**, or a single first emitter electrode shown here as a single wire or wire-shaped electrode **232**. (The terms "wire" and "wire-shaped" shall be used interchangeably herein to mean an electrode either made from a wire or, if thicker or stiffer than a wire, having the appearance of a wire.) In the embodiment shown, handle member **112** lifts second array electrodes **240** upward causing the second electrode to telescope out of the top of the housing and, if desired, out of unit **100** for cleaning, while the first electrode array **230** remains within unit **100**. As is evident from the figure, the second array of electrodes **240** can be lifted vertically out from the top **103** of unit **100** along the longitudinal axis or direction of the elongated housing **102**. This arrangement with the second electrodes removable from the top **103** of the unit **100**, makes it easy for the user to pull the second electrodes **242** out for cleaning. In Fig. 2B, the bottom ends of second electrodes **242** are connected to a member **113**, to which is attached a mechanism **500**, which includes a flexible member and a slot for capturing and cleaning the first electrode **232**, whenever handle member **112** is moved upward or downward by a user. The first and second arrays of electrodes are coupled to the output terminals of ion generating unit **160**.

[0023] The general shape of the embodiment of the invention shown in Figs. 2A and 2B is that of a figure eight in cross-section, although other shapes are within the spirit and scope of the invention. The top-to-bottom height in one preferred embodiment is, 1 m, with a left-to-right width

of preferably 15 cm, and a front-to-back depth of perhaps 10 cm, although other dimensions and shapes can of course be used. A louvered construction provides ample inlet and outlet venting in an ergonomical housing configuration. There need be no real distinction between vents **104** and **106,** except their location relative to the second electrodes. These vents serve to ensure that an adequate flow of ambient air can be drawn into or made available to the unit **100**, and that an adequate flow of ionized air that includes appropriate amounts of O_3 flows out from unit **100**.

[0024] As will be described, when unit **100** is energized by depressing switch **S1,** high voltage or high potential output by an ion generator **160** produces ions at the first electrode **232,** which ions are attracted to the second electrodes **242**. The movement of the ions in an "IN" to "OUT" direction carries with the ions air molecules, thus electro-kinetically producing an outflow of ionized air. The "IN" rotation in Figs. 2A and 2B denote the intake of ambient air with particulate matter **60**. The "OUT" notation in the figures denotes the outflow of cleaned air substantially devoid of the particulate matter, which particulates matter adheres electrostatically to the surface of the second electrodes. In the process of generating the ionized airflow appropriate amounts of ozone (O_3) are beneficially produced. It may be desired to provide the inner surface of housing **102** with an electrostatic shield to reduce detectable electromagnetic radiation. For example, a metal shield could be disposed within the housing, or portions of the interior of the housing can be coated with a metallic paint to reduce such radiation.

<u>Preferred Embodiments of Air-Transporter-Conditioner System with Germicidal Lamp</u>

[0025] Figs. 3A-6 depict various embodiments of the device **200**, with an improved ability to diminish or destroy microorganisms including bacteria, germs, and viruses. Specifically, Figs. 3A-6

illustrate various preferred embodiments of the elongated and upstanding housing **210** with the operating controls located on the top surface **217** of the housing **210** for controlling the device **200**.

Figs. 3A-3E

[0026] Fig. 3A illustrates a first preferred embodiment of the housing **210** of device **200**. The housing **210** is preferably made from a lightweight inexpensive material, ABS plastic for example. As a germicidal lamp (described hereinafter) is located within the housing **210**, the material must be able to withstand prolonged exposure to class UV-C light. Non "hardened" material will degenerate over time if exposed to light such as UV-C. By way of example only, the housing **210** may be manufactured from CYCLOLAC® ABS Resin, (material designation VW300(f2)) which is manufactured by General Electric Plastics Global Products, and is certified by UL Inc. for use with ultraviolet light. It is within the scope of the present invention to manufacture the housing **210** from other UV appropriate materials. .

[0027] In a preferred embodiment, the housing **210** is aerodynamically oval, elliptical, teardrop-shaped or egg-shaped. The housing **210** includes at least one air intake **250**, and at least one air outlet **260**. As used herein, it will be understood that the intake **250** is "upstream" relative to the outlet **260**, and that the outlet **260** is "downstream" from the intake **250**. "Upstream" and "downstream" describe the general flow of air into, through, and out of device **200**, as indicated by the large hollow arrows.

[0028] Covering the inlet **250** and the outlet **260** are fins, louvers, or baffles **212**. The fins **212** are preferably elongated and upstanding, and thus in the preferred embodiment, vertically oriented to minimize resistance to the airflow entering and exiting the device **200**. Preferably the

fins **212** are vertical and parallel to at least the second collector electrode array **240** (see Fig. 5A). The fins **212** can also be parallel to the first emitter electrode array **230**. This configuration assists in the flow of air through the device **200** and also assists in preventing UV radiation from the UV or germicidal lamp **290** (described hereinafter), or other germicidal source, from exiting the housing **210**. By way of example only, if the long width of the body from the inlet **250** to the outlet **260** is 8 inches, the collector electrode **242** (see Fig. 5A) can be 1 ¼" wide in the direction of airflow, and the fins **212** can be ¾" or ½" wide in the direction airflow. Of course, other proportionate dimensions are within the spirit and scope of the invention. Further, other fin and housing shapes which may not be as aerodynamic are within the spirit and scope of the invention. **[0029]** From the above it is evident that preferably the cross-section of the housing **210** is oval, elliptical, teardrop-shaped or egg shaped with the inlet **250** and outlet **260** narrower than the middle (see line A-A in Fig. 5A) of the housing **210**. Accordingly, the airflow, as it passes across line A-A, is slower due to the increased width and area of the housing **210**. Any bacteria, germs, or virus within the airflow will have a greater dwell time and be neutralized by a germicidal device, such as, preferably, an ultraviolet lamp.

[0030] Fig. 3B illustrates the operating controls for the device **200**. Located on top surface **217** of the housing **210** is an airflow speed control dial **214**, a boost button **216,** a function dial **218**, and an overload/cleaning light **219**. The airflow speed control dial **214** has three settings from which a user can choose: LOW, MED, and HIGH. The airflow rate is proportional to the voltage differential between the electrodes or electrode arrays coupled to the ion generator **160**. The LOW, MED, and HIGH settings generate a different predetermined voltage difference between the first and second arrays. For example, the LOW setting will create the smallest voltage difference, while the

HIGH setting will create the largest voltage difference. Thus, the LOW setting will cause the device **200** to generate the slowest airflow rate, while the HIGH setting will cause the device **200** to generate the fastest airflow rate. These airflow rates are created by the electronic circuit disclosed in Figs. 7A-7B, and operate as disclosed below.

[0031] The function dial **218** enables a user to select "ON," "ON/GP," or "OFF." The unit **200** functions as an electrostatic air transporter-conditioner, creating an airflow from the inlet **250** to the outlet **260**, and removing the particles within the airflow when the function dial **218** is set to the "ON" setting. The germicidal lamp **290** does not operate, or emit UV light, when the function dial **218** is set to "ON." The device **200** also functions as an electrostatic air transporter-conditioner, creating an airflow from the inlet **250** to the outlet **260**, and removing particles within the airflow when the function dial **218** is set to the "ON/GP" setting. In addition, the "ON/GP" setting activates the germicidal lamp **290** to emit UV light to remove or kill bacteria within the airflow. The device **200** will not operate when the function dial **218** is set to the "OFF" setting.

[0032] As previously mentioned, the device **200** preferably generates small amounts of ozone to reduce odors within the room. If there is an extremely pungent odor within the room, or a user would like to temporarily accelerate the rate of cleaning, the device **200** has a boost button **216**. When the boost button **216** is depressed, the device **200** will temporarily increase the airflow rate to a predetermined maximum rate, and generate an increased amount of ozone. The increased amount of ozone will reduce the odor in the room faster than if the device **200** was set to HIGH. The maximum airflow rate will also increase the particle capture rate of the device **200**. In a preferred embodiment, pressing the boost button **216** will increase the airflow rate and ozone production continuously for 5

minutes. This time period may be longer or shorter. At the end of the preset time period (e.g., 5 minutes), the device **200** will return to the airflow rate previously selected by the control dial **214**.

[0033] The overload/cleaning light **219** indicates if the second electrodes **242** require cleaning, or if arcing occurs between the first and second electrode arrays. The overload/cleaning light **219** may illuminate either amber or red in color. The light **219** will turn amber if the device **200** has been operating continuously for more than two weeks and the second array **240** has not been removed for cleaning within the two week period. The amber light is controlled by the below described micro-controller unit **130** (see Fig. 7). The device **200** will continue to operate after the light **219** turns amber. The light **219** is only an indicator. There are two ways to reset or turn the light **219** off. A user may remove and replace the second array **240** from the unit **200**. The user may also turn the control dial **218** to the OFF position, and subsequently turn the control dial **218** back to the "ON" or "ON/GP" position. The MCU **130** will begin counting a new two week period upon completing either of these two steps.

[0034] The light **219** will turn red to indicate that continuous arcing has occurred between the first array **230** and the second array **240**, as sensed by the MCU **130**, which receives an arc sensing signal from the collector of an IGBT switch **126** shown in Fig. 7, described in more detail below. When continuous arcing occurs, the device **200** will automatically shut itself off. The device **200** cannot be restarted until the device **200** is reset. To reset the device **200**, the second array **240** should first be removed from the housing **210** after the unit **200** is turned off. The second electrode **240** can then be cleaned and placed back into the housing **210**. Then, the device **200** is turned on. If no arcing occurs, the device **200** will operate and generate an airflow. If the arcing between the electrodes continues, the device **200** will again shut itself off, and need to be reset.

[0035] Fig. 3C illustrates the second electrodes **242** partially removed from the housing **210**. In this embodiment, the handle **202** is attached to an electrode mounting bracket **203**. The bracket **203** secures the second electrodes **242** in a fixed, parallel configuration. Another similar bracket **203** is attached to the second electrodes **242** substantially at the bottom (not shown). The two brackets **203** align the second electrodes **242** parallel to each other, and in-line with the airflow traveling through the housing **210**. Preferably, the brackets **203** are non-conductive surfaces.

[0036] One of the various safety features can be seen with the second electrodes **242** partially removed. As shown in Fig. 3C, an interlock post **204** extends from the bottom of the handle **202**. When the second electrodes **242** are placed completely into the housing **210**, the handle **202** rests within the top surface **217** of the housing, as shown by Figs. 3A-3B. In this position, the interlock post **204** protrudes into the interlock recess **206** and activates a switch connecting the electrical circuit of the unit **200**. When the handle **202** is removed from the housing **210**, the interlock post **204** is pulled out of the interlock recess **206** and the switch opens the electrical circuit. With the switch in an open position, the unit **200** will not operate. Thus, if the second electrodes **242** are removed from the housing **210** while the unit **200** is operating, the unit **200** will shut off as soon as the interlock post **204** is removed from the interlock recess **206**.

[0037] Fig. 3D depicts the housing **210** mounted on a stand or base **215**. The housing **210** has an inlet **250** and an outlet **260**. The base **215** sits on a floor surface. The base **215** allows the housing **210** to remain in a vertical position. It is within the scope of the present invention for the housing **210** to be pivotally connected to the base **215**. As can be seen in Fig. 3D, housing **210** includes sloped top surface **217** and sloped bottom surface **213**. These surfaces slope inwardly from inlet **250** to outlet **260** to additionally provide a streamline appearance and effect.

[0038] Fig. 3E illustrates that the housing **210** has a removable rear panel **224**, allowing a user to easily access and remove the germicidal lamp **290** from the housing **210** when the lamp **290** expires. This rear panel **224** in this embodiment defines the air inlet and comprises the vertical louvers. The rear panel **224** has locking tabs **226** located on each side, along the entire length of the panel **224**. The locking tabs **226**, as shown in Fig. 3E, are "L"-shaped. Each tab **224** extends away from the panel **224**, inward towards the housing **210**, and then projects downward, parallel with the edge of the panel **224**. It is within the spirit and scope of the invention to have differently shaped tabs **226**. Each tab **224** individually and slidably interlocks with recesses **228** formed within the housing **210**. The rear panel **224** also has a biased lever (not shown) located at the bottom of the panel **224** that interlocks with the recess **230**. To remove the panel **224** from the housing **210**, the lever is urged away from the housing **210**, and the panel **224** is slid vertically upward until the tabs **226** disengage the recesses **228**. The panel **224** is then pulled away from the housing **210**. Removing the panel **224** exposes the lamp **290** for replacement.

[0039] The panel **224** also has a safety mechanism to shut the device **200** off when the panel **224** is removed. The panel **224** has a rear projecting tab (not shown) that engages the safety interlock recess **227** when the panel **224** is secured to the housing **210**. By way of example only, the rear tab depresses a safety switch located within the recess **227** when the rear panel **224** is secured to the housing **210**. The device **200** will operate only when the rear tab in the panel **224** is fully inserted into the safety interlock recess **227**. When the panel **224** is removed from the housing **210**, the rear projecting tab is removed from the recess **227** and the power is cut-off to the entire device **200**. For example if a user removes the rear panel **224** while the device **200** is running, and the germicidal lamp **290** is emitting UV radiation, the device **200** will turn off as soon as the rear projecting tab

disengages from the recess **227**. Preferably, the device **200** will turn off when the rear panel **224** is removed only a very short distance (e.g., ¼") from the housing **210**. This safety switch operates very similar to the interlocking post **204**, as shown in Fig. 3C.

Fig.4

[0040] Fig. 4 illustrates yet another embodiment of the housing **210**. In this embodiment, the germicidal lamp **290** may be removed from the housing **210** by lifting the germicidal lamp **290** out of the housing **210** through the top surface **217**. The housing **210** does not have a removable rear panel **224**. Instead, a handle **275** is affixed to the germicidal lamp **290**. The handle **275** is recessed within the top surface **217** of the housing **210** similar to the handle **202**, when the lamp **290** is within the housing **210**. To remove the lamp **290**, the handle **275** is vertically raised out of the housing **210**.

[0041] The lamp **290** is situated within the housing **210** in a similar manner as the second array of electrodes **240**. That is to say, that when the lamp **290** is pulled vertically out of the top **217** of the housing **210**, the electrical circuit that provides power to the lamp **290** is disconnected. The lamp **290** is mounted in a lamp fixture that has circuit contacts which engages the circuit in Fig. 7A. As the lamp **290** and fixture are pulled out, the circuit contacts are disengaged. Further, as the handle **275** is lifted from the housing **210**, a cutoff switch will shut the entire device **200** off. This safety mechanism ensures that the device **200** will not operate without the lamp **290** placed securely in the housing **210**, preventing an individual from directly viewing the radiation emitted from the lamp **290**. Reinserting the lamp **290** into the housing **210** causes the lamp fixture to re-engage the circuit contacts as is known in the art. In similar, but less convenient fashion, the lamp **290** may be designed to be removed from the bottom of the housing **210**.

[0042] The germicidal lamp **290** is a preferably UV-C lamp that preferably emits viewable light and radiation (in combination referred to as radiation or light **280**) having wavelength of about 254 nm. This wavelength is effective in diminishing or destroying bacteria, germs, and viruses to which it is exposed. Lamps **290** are commercially available. For example, the lamp **290** may be a Phillips model TUV 15W/G15 T8, a 15 W tubular lamp measuring about 25 mm in diameter by about 43 cm in length. Another suitable lamp is the Phillips TUV 8WG8 T6, an 8 W lamp measuring about 15 mm in diameter by about 29 cm in length. Other lamps that emit the desired wavelength can instead be used.

<u>Figs. 5A-5B</u>

[0043] As previously mentioned, one role of the housing **210** is to prevent an individual from viewing, by way of example, ultraviolet (UV) radiation generated by a germicidal lamp **290** disposed within the housing **210**. Figs. 5A-5B illustrate preferred locations of the germicidal lamp **290** within the housing **210**. Figs. 5A-5B further show the spacial relationship between the germicidal lamp **290** and the electrode assembly **220**, and the germicidal lamp **290** and the inlet **250** and the outlet **260** and the inlet and outlet louvers. [0044] In a preferred embodiment, the inner surface **211** of the housing **210** diffuses or absorbs the UV light emitted from the lamp **290**. Figs. 5A-5B illustrate that the lamp **290** does emit some light **280** directly onto the inner surface **211** of the housing **210**. By way of example only, the inner surface **211** of the housing **210** can be formed with a non-smooth finish, or a non-light reflecting finish or color, to also prevent the UV-C radiation from exiting through either the inlet **250** or the outlet **260**. The UV portion of the radiation **280** striking the wall **211** will be absorbed and disbursed as indicated above.

[0045] As discussed above, the fins **212** covering the inlet **250** and the outlet **260** also limit any line of sight of the user into the housing **210**. The fins **212** are vertically oriented within the inlet **250** and the outlet **260**. The depth D of each fin **212** is preferably deep enough to prevent an individual from directly viewing the interior wall **211**. In a preferred embodiment, an individual cannot directly view the inner surface **211** by moving from side-to-side, while looking into the outlet **260** or the inlet **250**. Looking between the fins **212** and into the housing **210** allows an individual to "see through" the device **200**. That is, a user can look into the inlet vent **250** or the outlet vent **260** and see out of the other vent. It is to be understood that it is acceptable to see light or a glow coming from within housing **210**, if the light has a non-UV wavelength that is acceptable for viewing. In general, an user viewing into the inlet **250** or the outlet **260** may be able to notice a light or glow emitted from within the housing **210**. This light is acceptable to view. In general, when the radiation **280** strikes the interior surface **211** of the housing **210**, the radiation **280** is shifted from its UV spectrum. The wavelength of the radiation changes from the UV spectrum into an appropriate viewable spectrum. Thus, any light emitted from within the housing **210** is appropriate to view.

[0046] As also discussed above, the housing **210** is designed to optimize the reduction of microorganisms within the airflow. The efficacy of radiation **280** upon microorganisms depends upon the length of time such organisms are subjected to the radiation **280**. Thus, the lamp **290** is preferably located within the housing **210** where the airflow is the slowest. In preferred embodiments, the lamp **290** is disposed within the housing **210** along line A-A (see Figs. 5A-7). Line A-A designates the largest width and cross-sectional area of the housing **210**, perpendicular to the airflow. The housing **210** creates a fixed volume for the air to pass through. In operation, air enters the inlet **250**, which has a smaller width, and cross-sectional area, than along line A-A. Since

the width and cross-sectional area of the housing **210** along line A-A are larger than the width and cross-sectional area of the inlet **250**, the airflow will decelerate from the inlet **250** to the line A-A. By placing the lamp **290** substantially along line A-A, the air will have the longest dwell time as it passes through the radiation **280** emitted by the lamp **290**. In other words, the microorganisms within the air will be subjected to the radiation **280** for the longest period possible by placing the lamp **290** along line A-A. It is, however, within the scope of the present invention to locate the lamp **290** anywhere within the housing **210**, preferably upstream of the electrode assembly **220**.

[0047] A shell or housing **270** substantially surrounds the lamp **290**. The shell **270** prevents the light **280** from shining directly towards the inlet **250** or the outlet **260**. In a preferred embodiment, the interior surface of the shell **270** that faces the lamp **290** is a non-reflective surface. By way of example only, the interior surface of the shell **270** may be a rough surface, or painted a dark, non-gloss color such as black. The lamp **290**, as shown in Figs. 5A-5B, is a circular tube parallel to the housing **210**. In a preferred embodiment, the lamp **290** is substantially the same length as, or shorter than, the fins **212** covering the inlet **250** and outlet **260**. The lamp **290** emits the light **280** outward in a 360^0 pattern. The shell **270** blocks the portion of the light **280** emitted directly towards the inlet **250** and the outlet **260**. As shown in Figs. 5A and 5B, there is no direct line of sight through the inlet **250** or the outlet **260** that would allow a person to view the lamp **290**. Alternatively, the shell **270** can have an internal reflective surface in order to reflect radiation into the air stream.

[0048] In the embodiment shown in Fig. 5A, the lamp **290** is located along the side of the housing **210** and near the inlet **250**. After the air passes through the inlet **250**, the air is immediately exposed to the light **280** emitted by the lamp **290**. An elongated "U"-shaped shell **270** substantially

encloses the lamp **290**. The shell **270** has two mounts to support and electrically connect the lamp **290** to the power supply.

[0049] In a preferred embodiment, as shown in Fig. 5B, the shell **270** comprises two separate surfaces. The wall **274a** is located between the lamp **290** and the inlet **250**. The first wall **274a** is preferably "U"-shaped, with the concave surface facing the lamp **290**. The convex surface of the wall **274a** is preferably a non-reflective surface. Alternatively, the convex surface of the wall **274a** may reflect the light **280** outward toward the passing airflow. The wall **274a** is integrally formed with the removable rear panel **224**. When the rear panel **224** is removed from the housing **210**, the wall **274a** is also removed, exposing the germicidal lamp **290**. The germicidal lamp **290** is easily accessible in order to, as an example, replace the lamp **290** when it expires.

[0050] The wall **274b**, as shown in Fig. 5B, is "V"-shaped. The wall **274b** is located between the lamp **290** and the electrode assembly **220** to prevent a user from directly looking through the outlet **260** and viewing the UV radiation emitted from the lamp **290**. In a preferred embodiment, the wall **274b** is also a non-reflective surface. Alternatively, the wall **274b** may be a reflective surface to reflect the light **280**. It is within the scope of the present invention for the wall **274b** to have other shapes such as, but not limited to, "U"-shaped or "C"-shaped.

[0051] The shell **270** may also have fins **272**. The fins **272** are spaced apart and preferably substantially perpendicular to the passing airflow. In general , the fins **272** further prevent the light **280** from shining directly towards the inlet **250** and the outlet **260**. The fins have a black or non-reflective surface. Alternatively, the fins **272** may have a reflective surface. Fins **272** with a reflective surface may shine more light **280** onto the passing airflow because the light **280** will be repeatedly reflected and not absorbed by a black surface. The shell **270** directs the radiation towards

the fins **272**, maximizing the light emitted from the lamp **290** for irradiating the passing airflow. The shell **270** and fins **272** direct the radiation **280** emitted from the lamp **290** in a substantially perpendicular orientation to the crossing airflow traveling through the housing **210**. This prevents the radiation **280** from being emitted directly towards the inlet **250** or the outlet **260**.

Fig. 6

[0052] Fig. 6 illustrates yet another embodiment of the device **200**. The embodiment shown in Fig. 6 is a smaller, more portable, desk version of the air transporter-conditioner. Air is brought into the housing **210** through the inlet **250**, as shown by the arrows marked "IN." The inlet **250** in this embodiment is an air chamber having multiple vertical slots **251** located along each side. In this embodiment, the slots are divided across the direction of the airflow into the housing **210**. The slots **251** preferably are spaced apart a similar distance as the fins **212** in the previously described embodiments, and are substantially the same height as the side walls of the air chamber. In operation, air enters the housing **210** by entering the chamber **250** and then exiting the chamber **250** through the slots **251**. The air contacts the interior wall **211** of the housing **210** and continues to travel through the housing **210** towards the outlet **260**. Since the rear wall **253** of the chamber is a solid wall, the device **200** only requires a single non-reflective housing **270** located between the germicidal lamp **290** and the electrode assembly **220** and the outlet **260**. The housing **270** in Fig. 6 is preferably "U"-shaped, with the convex surface **270a** facing the germicidal lamp **290**. The surface **270a** directs the light **280** toward the interior surface **211** of the housing **210** and maximizes the disbursement of radiation into the passing airflow. It is within the scope of the invention for the surface **270** to comprise other shapes such as, but not limited to, a "V"-shaped surface, or to have the concave surface **270b** face the lamp **290**. Also in other embodiments the housing **270** can have a

reflective surface in order to reflect radiation into the air stream. Similar to the previous embodiments, the air passes the lamp **290** and is irradiated by the light **280** soon after the air enters the housing **210**, and prior to reaching the electrode assembly **220**.

[0053] Figs. 5A-6 illustrate embodiments of the electrode assembly **220**. The electrode assembly **220** comprises a first emitter electrode array **230** and a second particle collector electrode array **240**, which is preferably located downstream of the germicidal lamp **290**. The specific configurations of the electrode array **220** are discussed below, and it is to be understood that any of the electrode assembly configurations discussed below may be used in the device depicted in Figs. 2A-6. It is the electrode assembly **220** that creates ions and causes the air to flow electro-kinetically between the first emitter electrode array **230** and the second collector electrode array **240**. In the embodiments shown in Fig. 5A-6, the first array **230** comprises two wire-shaped electrodes **232**, while the second array **240** comprises three "U"-shaped electrodes **242**. Each "U"-shaped electrode has a nose **246** and two trailing sides **244**. It is within the scope of the invention for the first array **230** and the second array **240** to include electrodes having other shapes as mentioned above and described below.

[0054] <u>Electrical Circuit for the Electro-Kinetic Device:</u>

<u>FIG. 7</u>

[0055] Figs. 7 illustrates an electrical block diagram for the electro-kinetic device **200**, according to an embodiment of the present invention. The device **200** has an electrical power cord that plugs into a common electrical wall socket that provides a nominal 110VAC. An electromagnetic interference (EMI) filter **110** is placed across the incoming nominal 110VAC line to

reduce and/or eliminate high frequencies generated by the various circuits within the device **200**, such as an electronic ballast **112**. The electronic ballast **112** is electrically connected to the germicidal lamp **290** to regulate, or control, the flow of current through the lamp **290**. A switch **218** is used to turn the lamp **290** on or off. Electrical components such as the EMI Filter **110** and electronic ballast **112** are well known in the art and do not require a further description.

[0056] A DC Power Supply **114** is designed to receive the incoming nominal 110VAC and to output a first DC voltage (e.g., 160VDC) for the high voltage generator **170**. The first DC voltage (e.g., 160VDC) is also stepped down through a resistor network to a second DC voltage (e.g., about 12VDC) that the micro-controller unit (MCU) **130** can monitor without being damaged. The MCU **130** can be, for example, a Motorola 68HC908 series micro-controller, available from Motorola. In accordance with an embodiment of the present invention, the MCU **130** monitors the stepped down voltage (e.g., about 12VDC), which is labeled the AC voltage sense signal in Fig. 7, to determine if the AC line voltage is above or below the nominal 110VAC, and to sense changes in the AC line voltage. For example, if a nominal 110VAC increases by 10% to 121VAC, then the stepped down DC voltage will also increase by 10%. The MCU **130** can sense this increase and then reduce the pulse width, duty cycle and/or frequency of the low voltage pulses to maintain the output power (provided to the high voltage generator **170**) to be the same as when the line voltage is at 110VAC. Conversely, when the line voltage drops, the MCU **130** can sense this decrease and appropriately increase the pulse width, duty cycle and/or frequency of the low voltage pulses to maintain a constant output power. Such voltage adjustment features of the present invention also enable the same unit **200** to be used in different countries that have different nominal voltages than in the United States (e.g., in Japan the nominal AC voltage is 100VAC).

[0057] The high voltage pulse generator **170** is coupled between the first electrode array **230** and the second electrode array **240**, to provide a potential difference between the arrays. Each array can include one or more electrodes. The high voltage pulse generator **170** may be implemented in many ways. In the embodiment shown, the high voltage pulse generator **170** includes an electronic switch **126**, a step-up transformer **116** and a voltage doubler **118**. The primary side of the step-up transformer **116** receives the first DC voltage (e.g., 160VDC) from the DC power supply. An electronic switch receives low voltage pulses (of perhaps 20 -25 KHz frequency) from the micro-controller unit (MCU) **130**. Such a switch is shown as an insulated gate bipolar transistor (IGBT) **126**. The IGBT **126**, or other appropriate switch, couples the low voltage pulses from the MCU **130** to the input winding of the step-up transformer **116**. The secondary winding of the transformer **116** is coupled to the voltage doubler **118**, which outputs the high voltage pulses to the first and second electrode arrays **230** and **240**. In general, the IGBT **126** operates as an electronic on/off switch. Such a transistor is well known in the art and does not require a further description.

[0058] When driven, the generator **170** receives the low input DC voltage (e.g., 160VDC) from the DC power supply **114** and the low voltage pulses from the MCU **130**, and generates high voltage pulses of preferably at least 5 KV peak-to-peak with a repetition rate of about 20 to 25 KHz. Preferably, the voltage doubler **118** outputs about 6 to 9KV to the first array **230**, and about 12 to 18KV to the second array **240**. It is within the scope of the present invention for the voltage doubler **118** to produce greater or smaller voltages. The high voltage pulses preferably have a duty cycle of about 10%-15%, but may have other duty cycles, including a 100% duty cycle.

[0059] The MCU **130** receives an indication of whether the control dial **214** is set to the LOW, MEDIUM or HIGH airflow setting. The MCU **130** controls the pulse width, duty cycle and/or

frequency of the low voltage pulse signal provided to switch **126**, to thereby control the airflow output of the device **200**, based on the setting of the control dial **214**. To increase the airflow output, the MCU **130** can increase the pulse width, frequency and/or duty cycle . Conversely, to decrease the airflow output rate, the MCU **130** can reduce the pulse width, frequency and/or duty cycle. In accordance with an embodiment, the low voltage pulse signal (provided from the MCU **130** to the high voltage generator **170**) can have a fixed pulse width, frequency and duty cycle for the LOW setting, another fixed pulse width, frequency and duty cycle for the MEDIUM setting, and a further fixed pulse width, frequency and duty cycle for the HIGH setting. However, depending on the setting of the control dial **214**, the above described embodiment may produce too much ozone (e.g., at the HIGH setting) or too little airflow output (e.g., at the LOW setting). According, a more elegant solution, described below, is preferred.

[0060] In accordance with an embodiment of the present invention, the low voltage pulse signal created by the MCU **130** modulates between a "high" airflow signal and a "low" airflow signal, with the control dial setting specifying the durations of the "high" airflow signal and/or the "low" airflow signal. This will produce an acceptable airflow output, while limiting ozone production to acceptable levels, regardless of whether the control dial **214** is set to HIGH, MEDIUM or LOW. For example, the "high" airflow signal can have a pulse width of 5 microseconds and a period of 40 microseconds (i.e., a 12.5% duty cycle), and the "low" airflow signal can have a pulse width of 4 microseconds and a period of 40 microseconds (i.e., a 10% duty cycle). When the control dial **214** is set to HIGH, the MCU **130** outputs a low voltage pulse signal that modulates between the "low" airflow signal and the "high" airflow signal, with, for example, the "high" airflow signal being output for 2.0 seconds, followed by the "low" airflow signal being output for 8.0 second. When the control

dial **214** is set to MEDIUM, the "low" airflow signal can be increased to, for example, 16 seconds (e.g., the low voltage pulse signal will include the "high" airflow signal for 2.0 seconds, followed by the "low" airflow signal for 16 seconds). When the control dial **214** is set to LOW, the "low" airflow signal can be further increased to, for example, 24 seconds (e.g., the low voltage pulse signal will include a "high" airflow signal for 2.0 seconds, followed by the "low" airflow signal for 24 seconds).

[0061] Alternatively, or additionally, the frequency of the low voltage pulse signal (used to drive the transformer **116**) can be adjusted to distinguish between the LOW, MEDIUM and HIGH settings.

[0062] In accordance with another embodiment of the present invention, when the control dial **214** is set to HIGH, the electrical signal output from the MCU **130**, modulating between the "high" and "low" airflow signals, will continuously drive the high voltage generator **170**. When the control dial **214** is set to MEDIUM, the electrical signal output from the MCU **130** will cyclically drive the high voltage generator **170** for a predetermined amount of time (e.g., 25 seconds), and then drop to a zero or a lower voltage for a further predetermined amount of time (e.g., a further 25 seconds). Thus, the overall airflow rate through the device **200** is slower when the dial **214** is set to MEDIUM than when the control dial **214** is set to HIGH. When the control dial **214** is set to LOW, the signal from the MCU **130** will cyclically drive the high voltage generator **170** for a predetermined amount of time (e.g., 25 seconds), and then drop to a zero or a lower voltage for a longer time period (e.g., 75 seconds). It is within the scope and spirit of the present invention the the HIGH, MEDIUM, and LOW settings will drive the high voltage generator **170** for longer or shorter periods of time.

[0063] The MCU **130** provides the low voltage pulse signal, including "high" airflow signals and "low" airflow signals, to the high voltage generator **170**, as described above. By way of

example, the "high" airflow signal causes the voltage doubler **118** to provide 9KV to the first array **230**, while 18KV is provided to the second array **240**; and the "low" airflow signal causes the voltage doubler **118** to provide 6KV to the first array **230**, while 12KV is provided to the second array **240**. The voltage difference between the first array **230** and the second array **240** is proportional to the actual airflow output rate of the device **200**. In general, a greater voltage differential is created between the first and second array by the "high" airflow signal. It is within the scope of the present invention for the MCU **130** and the high voltage generator **170** to produce other voltage potential differentials between the first and second arrays **230** and **240**. The various circuits and components comprising the high voltage pulse generator **170** can, for example, be fabricated on a printed circuit board mounted within housing **210**. The MCU **130** can be located on the same or a different circuit board.

[0064] As mentioned above, device **200** includes a boost button **216**. In accordance with an embodiment of the present invention, when the MCU **130** detects that the boost button **216** has been depressed, the MCU **130** drives the high voltage generator **170** as if the control dial **214** was set to the HIGH setting for a predetermined amount of time (e.g., 5 minutes), even if the control dial **214** is set to LOW or MEDIUM (in effect overriding the setting specified by the dial **214**). This will cause the device **200** will run at a maximum airflow rate for the boost time period (e.g., a 5 minute period). Alternatively, the MCU **130** can drive the high voltage generator **170** to even further increase the ozone and particle capture rate for the boost time period. For example, the MCU **130** can continually provide the "high" airflow signal to the high voltage generator **170** for the entire boost time period, thereby creating increased amounts of ozone. The increased amounts of ozone will reduce the odor in a room faster than if the device **200** was set to HIGH. The maximum airflow rate will also

increase the particle capture rate of the device **200**. In a preferred embodiment, pressing the boost button **216** will increase the airflow rate and ozone production continuously for 5 minutes. This time period may be longer or shorter. At the end of the preset time period (e.g., 5 minutes), the device **200** will return to the airflow rate previously selected by the control dial **214**.

[0065] The MCU **130** can provide various timing and maintenance features. For example, the MCU **130** can provide a cleaning reminder feature (e.g., a 2 week timing feature) that provides a reminder to clean the device **200** (e.g., by causing indicator light **219** to turn on amber, and/or by triggering an audible alarm (not shown) that produces a buzzing or beeping noise). The MCU **130** can also provide arc sensing, suppression and indicator features, as well as the ability to shut down the high voltage generator **170** in the case of continued arcing. These and other features are described in additional detail below.

Arc Sensing and Suppression:

FIG. 8

[0066] The flow diagram of FIG. 8 is used to describe embodiments of the present invention that sense and suppress arcing between the first electrode array **230** and the second electrode array **240**. The process begins at step **802**, which can be when the function dial is turned from "OFF" to "ON" or "GP/ON." At a step **804**, an arcing threshold is set, based on the airflow setting specified (by a user) using the control dial **214**. For example, there can be a high threshold, a medium threshold and a low threshold. In accordance with an embodiment of the present invention, these thresholds are current thresholds, but it is possible that other thresholds, such as voltage thresholds, can be used. At a step **806**, an arc count is initialized. At a step **807** a sample count is initialized.

[0067] At a step **808**, a current associated with the electro-kinetic system is periodically sampled (e.g., one every 10 msec) to produce a running average current value. In accordance with an embodiment of the present invention, the MCU **130** performs this step by sampling the current at the emitter of the IGBT **126** of the high voltage generator **170** (see FIG. 7). The running average current value can be determined by averaging a sampled value with a previous number of samples (e.g., with the previous three samples). A benefit of using averages, rather than individual values, is that averaging has the effect of filtering out and thereby reducing false arcing detections. However, in alternative embodiments no averaging is used.

[0068] At a next step **810**, the average current value determined at step **808** is compared to the threshold value, which was specified at step **804**. If the average current value does not equal or exceed the threshold value (i.e., if the answer to step **810** is NO), then there is a determination at step **822** of whether the threshold has not been exceeded during a predetermined amount of time (e.g., over the past 60 seconds). If the answer to step **822** is NO (i.e., if the threshold has been exceeded during the past 60 seconds), then flow returns to step **808**, as shown. If the answer to step **822** is YES, then there is an assumption that the cause for any previous arcing is no longer present, and flow returns to step **806** and the arc count and the sample count are both reinitialized. Returning to step **810**, if the average current value reaches the threshold, then it is assumed that arcing has been detected (because arcing will cause an increase in the current), and the sample count is incremented at a step **812**.

[0069] The sample count is then compared to a sample count threshold (e.g., the sample count threshold = 30) at a step **814**. Assuming, for example, a sample count threshold of 30, and a sample frequency of 10 msec, then the sample count equaling the sample count threshold

corresponds to an accumulated arcing time of 300 msec (i.e., 10 msec * 30 = 300 msec). If the sample count has not reached the sample count threshold (i.e., if the answer to step **814** is NO), then flow returns to step **808**. If the sample count equals the sample count threshold, then the MCU **130** temporarily shuts down the high voltage generator **170** (e.g., by not driving the generator **170**) for a predetermined amount of time (e.g., 80 seconds) at a step **816**, to allow a temporary condition causing the arcing to potentially go away. For examples: temporary humidity may have caused the arcing; or an insect temporarily caught between the electrode arrays **230** and **240** may have caused the arcing. Additionally, the arc count is incremented at step **818**.

[0070] At a step **820**, there is a determination of whether the arc count has reached the arc count threshold (e.g., the arc count threshold = 3), which would indicate unacceptable continued arcing. Assuming, for example, a sample count threshold of 30, and a sample frequency of 10 msec, and an arc count threshold of 3, then the arc count equaling the arc count threshold corresponds to an accumulated arcing time of 900 msec (i.e., 3* 10 msec * 30 = 300 msec). If the arc count has not reached the arc count threshold (i.e., if the answer to step **820** is NO), then flow returns to step **807**, where the sample count is reset to zero, as shown. If the arc count equals the arc count threshold (i.e., if the answer to step **820** is YES), then the high voltage generator **170** is shut down at step **824**, to prevent continued arcing from damaging to the device **200** or producing excessive ozone. At this point, the MCU **130** causes the overload/cleaning light **219** to light up red, thereby notifying the user that the device **200** has been "shut down." The term "shut down," in this respect, means that the MCU **130** stops driving the high voltage generator **170**, and thus the device **200** stops producing ion and ozone containing airflow. However, even after "shut down," the MCU **130** continues to operate.

[0071] Once the device **200** is shut down at step **824**, the MCU **130** will not again drive the high voltage generator **170** until the device **200** is reset. In accordance with an embodiment of the present invention, the device **200** can be reset by turning it off and back on (e.g., by turning function dial **218** to "OFF" and then to "ON" or "ON/GP"), which will in effect re-initialize the counters at step **806** and **807**. Alternatively, or additionally, the device **200** includes a sensor, switch, or other similar device, that is triggered by the removal of the second electrode array **240** (presumably for cleaning) and/or by the replacement of the second electrode array **240**. The device can alternately or additionally include a reset button or switch. The sensor, switch, resset button/switch or other similar device, provides a signal to the MCU **130** regarding the removal and/or replacement of the second electrode array **240**, causing the MCU **130** to re-initialize the counters (at step **806** and **807**) and again drive the high voltage generator **170**.

[0072] Arcing can occur, for example, because of a carbon path is produced between the first electrode array **230** and the second electrode array **240**, e.g., due to a moth or other insect that got caught in the device **200**. Assuming the first and/or second electrode arrays **230** and **240** are appropriately cleaned prior to the device **200** being reset, the device should operate normally after being reset. However, if the arc causing condition (e.g., the carbon path) persists after the device **200** is reset, then the features described with reference to FIG. 8 will quickly detect the arcing and again shut down the device **200**.

[0073] More generally, embodiments of the present invention provide for temporary shut down of the high voltage generator **170** to allow for a temporary arc creating condition to potentially go away, and for a continued shut down of the high voltage generator **170** if the arcing continues for an unacceptable duration. This enables the device **200** to continue to provide desirable quantities of

ions and ozone (as well as airflow) following temporary arc creating conditions. This also provides for a safety shut down in the case of continued arcing.

[0074] In accordance with alternative embodiments of the present invention, at step **816** rather than temporarily shutting down the high voltage generator **170** for a predetermined amount of time, the power is temporarily lowered. The MCU **130** can accomplish this by appropriately adjusting the signal that it uses to drive the high voltage generator **170**. For example, the MCU **130** can reduce the pulse width, duty cycle and/or frequency of the low voltage pulse signal provided to switch **126** for a pre-determined amount of time before returning the low voltage pulse signal to the level specified according to the setting of the control dial **214**. This has the effect of reducing the potential difference between the arrays **230** and **240** for the predetermined amount of time.

[0075] It would be apparent to one of ordinary skill in the relevant art that some of the steps in the flow diagram of FIG. 8 need not be performed in the exact order shown. For example, the order of steps 818 and 816 can be reversed or these steps can be performed simultaneously. However, it would also be apparent to one of ordinary skill in the relevant art that some of the steps should be performed before others. This is because certain steps use the results of other steps. The point is, the order of the steps is typically only important where a step uses results of another step. Accordingly, one of ordinary skill in the relevant art would appreciate that embodiments of the present invention should not be limited to the exact orders shown in the figures. Additionally, one of ordinary skill in the relevant art would appreciate that embodiments of the present invention can be implemented using subgroups of the steps that are shown in the figures.

[0076] In accordance with embodiments of the present invention, rather than periodically sampling a current or voltage associated with the electro-kinetic system at step **808**, the MCU **130**

can more continually monitor or sample the current or voltage associated with the electro-kinetic system so that even narrow transient spikes (e.g., of about 1 msec. in duration) resulting from arcing can be detected. In such embodiments, the MCU **130** can continually compare an arc sensing signal to an arcing threshold (similar to step **810**). For example, when the arc sensing signal reaches or exceeds the arcing threshold a triggering event occurs that causes the MCU **130** to react (e.g., by incrementing a count, as in step **812**). If the arcing threshold is exceeded more than a predetermined number of times (e.g., once, twice or three times, etc.) within a predetermined amount of time, then the unit **200** is temporarily shut down (similar to steps **810-816**). If arcing is not detected for a predetermined amount of time, then an arcing count can be reset (similar to step **822**). Thus, the flow chart of Fig. 8 applies to these event type (e.g., by interrupt) monitoring embodiments.

<u>Other Electrode Configurations:</u>

[0077] In practice, unit **200** is placed in a room and connected to an appropriate source of operating potential, typically 110 VAC. The energizing ionization unit **200**, emits ionized air and ozone via outlet vents **260**. The airflow, coupled with the ions and ozone freshens the air in the room, and the ozone can beneficially destroy or at least diminish the undesired effects of certain odors, bacteria, germs, and the like. The airflow is indeed electro-kinetically produced, in that there are no intentionally moving parts within unit. (Some mechanical vibration may occur within the electrodes).

[0078] In the various embodiments, electrode assembly **220** comprises a first array **230** of at least one electrode or conductive surface, and further comprises a second array **240** of at least one electrode or conductive surface. Material(s) for electrodes, in one embodiment, conduct electricity,

are resistant to corrosive effects from the application of high voltage, yet be strong enough to be cleaned.

[0079] In the various electrode assemblies to be described herein, electrode(s) **232** in the first electrode array **230** can be fabricated, for example, from tungsten. Tungsten is sufficiently robust in order to withstand cleaning, has a high melting point to retard breakdown due to ionization, and has a rough exterior surface that seems to promote efficient ionization. On the other hand, electrode(s) **242** in the second electrode array **240** can have a highly polished exterior surface to minimize unwanted point-to-point radiation. As such, electrode(s) **242** can be fabricated, for example, from stainless steel and/or brass, among other materials. The polished surface of electrode(s) **242** also promotes ease of electrode cleaning.

[0080] The electrodes can be lightweight, easy to fabricate, and lend themselves to mass production. Further, electrodes described herein promote more efficient generation of ionized air, and appropriate amounts of ozone, (indicated in several of the figures as O_3).

[0081] Various electrode configurations for use in the device **200** are described in U.S. Patent Application Serial Number 10/074,082, filed February 12, 2002, entitled "Electro-Kinetic Air Transporter-Conditioner Devices with an Upstream Focus Electrode," incorporated herein by reference, and in the related application mentioned above.

[0082] In one embodiment, the positive output terminal of high voltage generator **170** is coupled to first electrode array **230**, and the negative output terminal is coupled to second electrode array **240**. It is believed that with this arrangement the net polarity of the emitted ions is positive, *e.g.*, more positive ions than negative ions are emitted. This coupling polarity has been found to work well, including minimizing unwanted audible electrode vibration or hum. However, while

generation of positive ions is conducive to a relatively silent airflow, from a health standpoint, it is desired that the output airflow be richer in negative ions, not positive ions. It is noted that in some embodiments, one port (such as the negative port) of the high voltage pulse generator **170** can in fact be the ambient air. Thus, electrodes in the second array need not be connected to the high voltage pulse generator using a wire. Nonetheless, there will be an "effective connection" between the second array electrodes and one output port of the high voltage pulse generator, in this instance, via ambient air. Alternatively the negative output terminal of the high voltage pulse generator **170** can be connected to the first electrode array **230** and the positive output terminal can be connected to the second electrode array **240**. In either embodiment, the high voltage generator **170** will produce a potential difference between the first electrode array **230** and the second electrode array **240**.

[0083] When voltage or pulses from high voltage pulse generator **170** are coupled across first and second electrode arrays **230** and **240**, a plasma-like field is created surrounding electrodes in first array **230**. This electric field ionizes the ambient air between the first and second electrode arrays and establishes an "OUT" airflow that moves towards the second array.

[0084] Ozone and ions are generated simultaneously by the first array electrodes **230**, essentially as a function of the potential from generator **170** coupled to the first array of electrodes or conductive surfaces. Ozone generation can be increased or decreased by increasing or decreasing the potential at the first array. Coupling an opposite polarity potential to the second array electrodes **240** essentially accelerates the motion of ions generated at the first array, producing the out airflow. As the ions and ionized particulate move toward the second array, the ions and ionized particles push or move air molecules toward the second array. The relative velocity of this motion may be increased,

by way of example, by decreasing the potential at the second array relative to the potential at the first array.

[0085] For example, if +10 KV were applied to the first array electrode(s), and no potential were applied to the second array electrode(s), a cloud of ions (whose net charge is positive) would form adjacent the first electrode array. Further, the relatively high 10 KV potential would generate substantial ozone. By coupling a relatively negative potential to the second array electrode(s), the velocity of the air mass moved by the net emitted ions increases.

[0086] On the other hand, if it were desired to maintain the same effective outflow (OUT) velocity, but to generate less ozone, the exemplary 10 KV potential could be divided between the electrode arrays. For example, generator **170** could provide +4 KV (or some other fraction) to the first array electrodes and -6 KV (or some other fraction) to the second array electrodes. In this example, it is understood that the +4 KV and the -6 KV are measured relative to ground. Understandably it is desired that the unit **200** operates to output appropriate amounts of ozone. Accordingly, in one embodiment, the high voltage is fractionalized with about +4 KV applied to the first array electrodes and about -6 KV applied to the second array electrodes.

[0087] In one embodiment, electrode assembly **220** comprises a first array **230** of wire-shaped electrodes, and a second array **240** of generally "U"-shaped electrodes **242**. In some embodiments, the number N1 of electrodes comprising the first array **230** can differ by one relative to the number N2 of electrodes comprising the second array **240**. In many of the embodiments shown, N2>N1. However, if desired, additional first electrodes could be added at the outer ends of array such that N1>N2, *e.g.*, five first electrodes compared to four second electrodes.

[0088] As previously indicated first or emitter electrodes **232** can be lengths of tungsten wire, whereas collector electrodes **242** can be formed from sheet metal, such as stainless steel, although brass or other sheet metal could be used. The sheet metal can be readily configured to define side regions and bulbous nose region, forming a hollow, elongated "U"-shaped electrodes, for example.

[0089] In one embodiment, the spaced-apart configuration between the first and second arrays **230** and **240** is staggered. Each first array electrode **232** can be substantially equidistant from two second array electrodes **242**. This symmetrical staggering has been found to be an efficient electrode placement. The staggering geometry can be symmetrical in that adjacent electrodes or adjacent electrodes are spaced-apart a constant distance, Y1 and Y2 respectively. However, a non-symmetrical configuration could also be used. Also, it is understood that the number of electrodes may differ from what is shown.

[0090] In one embodiment ionization occurs as a function of a high voltage electrodes. For example for increasing the peak to peak voltage amplitude and the duty cycle of the pulses form the high voltage pulse generator **170** can increase ozone content in the output flow of ionized air.

[0091] In one embodiment, the second electrodes **242** can include a trail electrode pointed region which help produce the output of negative ions. In one embodiment the electrodes of the second array **242** of electrodes is "U" shaped. One embodiment a single pair of "L" shaped electrode(s) in cross section can be additionally used.

[0092] In one embodiment, the electrodes assembly **220** has a focus electrode(s). The focus electrodes can produce an enhanced air flow exiting the devices. The focus electrode can have a shape that does not have sharp edges manufactured from a material that will not erode or oxides existing with steel. In one embodiment, the diameter of the focus electrode is 15 times greater than

the diameter of the first electrode. The diameter of the focus electrode can be selected such that the focus electrode does not function as an ion generating surface. In one embodiment, the focus electrodes are electrically connected to the first array **230.** Focus electrodes help direct the air flow toward the second electrode for guiding it towards particles towards the trailing sides of the second electrode.

[0093] The focus electrodes can be "U" or "C" shaped with holes extending there through to minimize the resistance of the focus electrode on the air flow rate. In one embodiment, the electrode assembly **220** has a pin-ring electrode assembly. The pin-ring electrode assembly includes a pin, cone or triangle shaped, first electrode and a ring shaped second electrode (with an opening) down-stream of the first electrode.

[0094] The system can use an additional downstream trailing electrode. The trailing electrode can be aerodynamically smooth so as not to interfere with the air flow. The trailing electrodes can have a negative electoral charge to reduce positive charged particles in the air flow. Trailing electrodes can also be floating or set to ground. Trailing electrodes can act as a second surface to collect positively charged particles. Trailing electrodes can also reflect charged particles towards the second electrodes **242**. The trailing electrodes can also emit a small amount of negative ions into the air flow which can neutralize the positive ions emitted by the first electrodes **232**.

[0095] The assembly can also use interstitial electrodes positioned between the second electrodes **242**. The interstitial electrodes can float, be set to ground, or be put at a positive high voltage, such as a portion of the first electrode voltage. The interstitial electrodes can deflect particulate towards the second electrodes.

[0096] The first electrodes **232** can be made slack, kinked or coiled in order to increase the amount of ions emitted by the first electrode array **230**. Additional details about all of the above described electrode configurations are provided in the above mentioned applications, that have been incorporated herein by reference.

[0097] The foregoing description of the preferred embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations will be apparent to the practitioner skilled in the art. Modifications and variations may be made to the disclosed embodiments without departing from the subject and spirit of the invention as defined by the following claims. Embodiments were chosen and described in order to best describe the principles of the invention and its practical application, thereby enabling others skilled in the art to understand the invention, the various embodiments and with various modifications that are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.